

Survey of Current Practice for Design of High Strength Concrete Prestressed Bridge Girders

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Survey of Current Practice for Design of High Strength Concrete Prestressed Bridge Girders

By Mary Beth D. Hueste and Gladys G. Cuadros

A survey was conducted to determine the current state of practice for the design of high strength concrete (HSC) prestressed bridge girders among the 52 Departments of Transportation (DOTs) in the United States. A total of 41 responses were received during a six-month period spanning from June through November of 2002. It was found that the *AASHTO Standard Specifications for Highway Bridges*, 16th Edition, is the most popular code for bridge design in current practice. In most cases where the *AASHTO LRFD Bridge Design Specifications* are used, their implementation is partial, and most states plan complete implementation between 2003 and 2007. The state DOTs have a large variation in the number of new bridges constructed, with a range of 4 to 400 bridges per year. Of these numbers, the percentages of bridges constructed with HSC prestressed girders range from 0 to 100 percent among the DOTs. Nevertheless, the total number of bridges constructed per year using HSC prestressed girders is significant. HSC is widely used in current practice, with 85 percent of the responding DOTs using specified concrete compressive strength values at service in the range of 6000 to 8000 psi. In this study, the definition of HSC is concrete with specified compressive strengths for design of 6000 psi or greater, made without using exotic materials or techniques. It was reported that in some cases, concrete mixture designs are governed by the specified concrete compressive strength at release. This parameter tends to be critical when it is greater than 6000 psi. Almost half of the DOTs have some concerns related to the use of HSC, and seven DOTs have made in-house adjustments to the design specifications for HSC prestressed bridge girders.

INTRODUCTION

A survey entitled “Current Practice for Design of High Strength Concrete Prestressed Members” was developed and distributed to all 52 state departments of transportation (DOTs). The objective of this survey was to gather information and document critical aspects of current practice for the design of high strength concrete (HSC) prestressed bridge girders. Responses were received during a six-month period spanning from June through November of 2002. This study is part of the Texas Department of Transportation Research Project 0-2101, “Allowable Stresses and Resistance Factors for High Strength Concrete.” Hueste et al. (1) summarized the complete project and Hueste and Cuadros (2) documented the responses to the survey.

The questionnaire consists of two parts. “Part I: Current Design Practice for HSC Prestressed Bridge Members” contains 11 questions related to current specifications, additional documents and references, construction using HSC, typical range of specified concrete strengths at transfer and at service, concerns related to the use of HSC, and adjustments to the design specifications for HSC. “Part II: Description of Typical Bridges using HSC Prestressed Bridge Members” provides information on the span lengths and concrete strengths for a number of bridge types for which the respondents have used HSC. Responses from 41 state DOTs were collected, giving a 79 percent response rate from this group. The respondents are listed within the reported results. Of the 41 state DOTs that provided a response; only one did not give permission to identify their organization when reporting their response. This DOT is identified as “Undisclosed DOT.” Two Texas DOT (TxDOT) design offices were included in the survey: the Austin state office and the Houston district office. The following sections summarize the survey responses.

PART I: CURRENT DESIGN PRACTICE FOR HSC PRESTRESSED MEMBERS

Current Specifications

The first three questions of the survey address the current specifications in use for bridge design, as follows.

- Q 1: Current specification used by your organization for bridge member design.
- Q 2: If your organization is currently using the AASHTO LRFD Specifications, when were they implemented in your state (provide year)?
- Q 3: If your organization plans to use the AASHTO LRFD Specifications in the future, when do you foresee their implementation in your state (provide year)?

Table 1 shows the responses related to current specifications in use for bridge design and the implementation of the *AASHTO LRFD Bridge Design Specifications* (5). The survey indicates that the changeover to the LRFD Specifications is gradual. The *AASHTO Standard Specifications for Highway Bridges*, 16th Edition (3) is the most popular code for bridge design in current U.S. practice.

For the 41 DOTs involved in the survey, 23 (56 percent) are currently using the AASHTO Standard Specifications, nine (22 percent) are using the AASHTO LRFD Specifications, and nine (22 percent) are using both specifications. It should be noted that in most cases where the LRFD Specifications are used, their implementation is partial, and most states plan complete implementation in the period of 2003 to 2007.

Additional Design Documents and References

Questions 4 and 5 of the survey request information on additional relevant design documents used by the respondents, as follows.

- Q 4: Please list any other documents used by your organization for the design of prestressed concrete bridge girders.
- Q 5: Please list any additional reference documents used by your organization for design of HSC members.

Table 2 shows additional design documents and references for respondents to this question. The survey shows that about one-third of the state DOTs use additional documents and references for the design of prestressed concrete bridge girders and HSC members. Among these documents and references are the *Precast/Prestressed Concrete Institute (PCI) Bridge Design Manual* (6), some publications on HSC issued by the Portland Cement Association, bridge design manuals developed by individual state DOTs, software programs developed by state DOTs or software companies, and other reports and texts.

HSC Prestressed Bridge Girder Precasters

Precasters' names and locations were surveyed in Question 6, as follows.

- Q 6: Please provide the names and locations of precasters that supply HSC prestressed girders for your bridge projects.

A total of 35 state DOTs responded to this question. The survey indicates that one to seven precasters serve a DOT. For example, five precasters are supplying Florida and Iowa, six precasters are supplying Massachusetts, and seven precasters were noted as serving North Carolina and Texas. It should also be mentioned that precasters serving a state DOT are not always located in the same state. For example, Florida has five precasters supplying HSC prestressed girders, of which two are located in other states (Mississippi and Georgia). Hueste and Cuadros (2) summarize the names of the precasters that supply each state and their corresponding locations.

Prevalence of HSC Prestressed Bridge Girders

The number of HSC prestressed bridge girders constructed by state DOTs was surveyed in Question 7, as follows.

- Q 7: How many bridges does your organization typically construct each year? Of these, what percentage use HSC prestressed bridge girders (specified compressive strength $f'_c > 6000$ psi)?

Note that in this study, the definition of HSC is concrete with specified compressive strengths for design of 6000 psi or greater, made without using exotic materials or techniques (7). Table 3 shows the number of bridges that state DOTs typically construct per year. A large variation, from 4 to 400, was reported. Of these numbers, the percentages of bridges constructed with HSC prestressed girders are also shown, with a range of 0 to 100 percent.

In general 68 percent of the responding DOTs use HSC prestressed girders for 0 to 50 percent of their total construction, 15 percent of the responding DOTs use HSC prestressed girders for 51 to 80 percent of their total construction, and 17 percent of the responding DOTs use HSC prestressed girders for 81 to 100 percent of their total construction. Among the DOTs with the highest rate of HSC prestressed bridge girders construction are the DOTs that also have a significant number of bridges constructed per year, such as Florida, Georgia and Michigan. These

states construct from 60 to 100 bridges per year. It should be noted that DOTs with the highest number of bridges constructed per year, such as Illinois (400), Texas (360), Missouri (250), Pennsylvania (250), New York (236), California (200), Wisconsin (200) and Ohio (150) have the lowest percentage of construction using HSC. For example, in Illinois, of 400 bridges built, no bridges were constructed using HSC. In Texas, which constructs the second largest number of bridges per year (360), only 18 percent of the total construction utilizes HSC prestressed girders, as reported by the Austin office. However, this does result in a significant number of bridges using HSC prestressed girders in Texas. In TxDOT's Houston office, 75 percent of the total number of bridges constructed per year (50) is also a significant number of bridges using HSC.

Specified Concrete Strength

Question 8 of the survey focused on determining the range of the specified concrete strength for prestressed concrete bridge girders, as follows.

- Q 8: Please provide the typical range of specified strength for prestressed concrete bridge girders used in current projects for your organization?

Table 4 shows typical ranges for specified concrete strength at transfer and service conditions for current projects. The required concrete strength at transfer ranges from 3500 to 9000 psi, while the required concrete strength at service ranges from 4000 to 12000 psi. It should be noted that TxDOT reported designs for longer spans that required f'_c up to 14000 psi, however this strength was not reported as a typical value.

The responses to the survey indicate that the most popular range for the concrete strength at transfer ranges from 4000 to 7000 psi, and from 5000 to 8500 psi for the concrete strength at service. About 7 percent of the DOTs utilize a higher concrete strength at transfer (8000 psi) for some cases, and a 15 percent utilize a higher concrete strength at service (10000 psi) for some cases. Only 2 percent of the responding DOTs utilize a f'_c at service of 12000 psi and 7 percent of DOTs utilize a lower concrete strength at service of 4000 psi. There is significant use of f'_c values at service in the range of 6000 to 8000 psi (85 percent of total DOTs) indicating that HSC is widely used in current practice.

Impact of Required Transfer Strengths

The impact of high concrete strength requirements at transfer was surveyed in Question 9, as follows.

- Q 9: Please comment on whether the need to meet the required concrete compressive strength at transfer (f'_{ci}) in a short period of time has led to a practice where precasters use mix designs that give a significantly larger value of f'_c in service than specified. If this practice has been observed by your organization, can you give any specific information as to how this over-strength varies as a function of specified f'_{ci} and f'_c values?

Table 5 identifies positive and negative responses to Question 9 as well as some specific information given by the DOTs. Twenty-two of the responding state DOTs have observed that high initial concrete strength requirements have led to an over-strength in f'_c at service. Positive responses indicate that in some cases (in general when $f'_{ci} > 6000$ psi) mixture designs are governed by the specified concrete compressive strength at release. Thus, the specified release strength tends to be critical for HSC prestressed girder production.

In this study the definition of HSC is concrete with specified compressive strengths for design of 6000 psi or greater, made without using exotic materials or techniques (7). However, most of the responses indicate that high transfer strengths require special materials or techniques like accelerated curing. Two approaches for obtaining HSC are noted by the respondents. First, is to obtain a high initial concrete strength (within 18 hours to two days) using high early cement and/or heat curing. In this case, the final strengths tend to level off quickly (around seven days) and the strength gain is not significant. High early strengths obtained with accelerated curing methods (heat/steam) are known to attain lower strengths at 28 days than if cured under ambient conditions (see Rhode Island DOT response in Table 5). Second, is the common method of curing at ambient conditions, which tends to provide final strengths higher than those specified. In this case, if precasters focus on achieving the high initial concrete strength demands (within 18 hours to two days) with ambient curing methods, then the specified 28 day strength is met quickly and larger concrete strengths can be achieved at 28 days.

Concerns Related to the Use of HSC

Question 10 requests information about concerns related to the use of HSC prestressed bridge girders, as follows.

- Q 10: Please note any concerns you have related to the use of HSC prestressed bridge girders.

Table 6 identifies positive and negative responses for Question 10 as well as some specific information given by the states DOTs. The responses indicate that almost half of the DOTs have some concerns related to the use of HSC. Some of the general concerns are discussed below.

Transportation of Larger Span Lengths

Maximum span lengths are limited by transportation of the girders. In such cases, HSC may be used to increase girder spacings. According to TxDOT design recommendations (8), maximum span lengths of prestressed concrete beams constructed economically can go up to 130 ft. for U54 beams with girder spacing of 9.75 ft. using normal concrete strength (NSC), and up to 130 ft. for Type IV beams (no value was found for the girder spacing) using NSC. However, TxDOT design recommendations mentioned that a recent project in San Angelo, Texas utilized HSC with a concrete strength of 14000 psi to construct a 153 ft. span with Type IV beams (8). Moreover, the same document states that beams up to 150 ft. have been successfully transported, although at a premium cost.

Design Parameters for HSC

There is concern that design parameters in the AASHTO Specifications need to be upgraded for HSC. Several DOTs are reluctant to specify concrete compressive strengths at service (f'_c) higher than 8500 psi. The survey showed that the most popular range for the concrete strength at transfer (f'_{ci}) ranges from 4000 to 7000 psi, and at service typical f'_c values range from 5000 to 8500 psi. However, 15 percent of the DOTs utilize a higher concrete strength at service (10000 psi) for some cases, and a 2 percent of the DOTs that utilize a concrete strength at service of 12000 psi. It should be noted that the design equations in the AASHTO codes for prestressed concrete members are based on mechanical properties of normal strength concrete. Information about the mechanical properties for HSC produced by Texas precasters can be found in Hueste et al. (1,9).

Cracking

Initial cracking of girders during casting and before the release stage is a concern. TxDOT practice indicates that cracking at release is not a major problem because if a crack occurs in the top of the beam at the end regions, it will close when the concrete slab is poured.

Additional Concerns

Additional concerns include difficulties in providing 0.6 in. diameter strands at the proper spacing for some standard girder cross-sections. Also, research is needed to address critical issues, such as over-estimation of losses, determination of creep, shrinkage and camber for HSC. In some areas, suitable aggregates are not available; and in some cases, there are no qualified precasters to produce HSC prestressed girders.

Adjustments to Design Specifications for HSC Prestressed Bridge Girders

Question 11 of the survey requests information on adjustments applied to the specifications when designing HSC prestressed bridge girders, as follows.

- Q 11: Has your organization made any adjustment to the design specifications for HSC prestressed bridge girders based on research findings (such as in the allowable stresses or resistance factors)? If so, please describe and provide a reference to relevant research, if available.

Table 7 identifies positive and negative responses for this question, as well as some specific information given by the respondents. The survey indicates that most of the DOTs have not made adjustments to the design specifications for HSC prestressed bridge girders. Of the seven DOTs that have modifications, Minnesota and South Dakota have modified the equation for the modulus of elasticity; and Washington has modified the allowable stresses and equations for losses, creep and camber based in house-practice. Louisiana is conducting research that will be completed in 2003, and it is expected that the allowable stresses or resistance will change based on these findings.

PART II: DESCRIPTION OF TYPICAL BRIDGES WITH HSC PRESTRESSED BRIDGE MEMBERS

General

Part II of the survey focused on determining basic characteristics of typical bridges with HSC prestressed bridge girders used by the state DOTs. More specifically, the content of Part II of the questionnaire is as follows.

Part II: Description of Typical Bridges with HSC Prestressed Bridge Members

- In the following table, please provide the following information based on the practices of your organization (see Table 8).
- Indicate the types of bridges for which HSC prestressed bridge girders have been used by your organization.
- Provide the ranges for span length and concrete compressive strength (f'_c), for each structural type selected.
- Note how prevalent each type is for HSC prestressed bridge members, by filling in the percentage column.

It should be noted that the information requested regarding the prevalence of each structural type for HSC prestressed bridge members seems to have been interpreted in different ways. However, the reported values are included in the following tables for completeness. In addition, although an f'_c less than 6000 psi was not considered to be HSC for this study, some lower strength values were reported, and are included in the results.

Figure 1 shows the prevalence of different types of prestressed concrete bridges. It is evident that the AASHTO and bulb beams are the most predominant prestressed girder type among the DOTs. It was found that the most popular HSC girder type among the responding DOTs is the AASHTO beam (26 states) followed by the bulb beam (23 states) and the box girder (11 states). Voided slabs (6 states), slabs (4 states), double T beams (4 states) and closed box CIP beams (1 state) are the structural types with less use, although the cast-in-place (CIP) closed box is used for long spans (typically up to 150 ft.). It should be noted that the Texas U beams are used not only in Texas, but also in Colorado and New Mexico. Table 9 summarizes the findings for typical ranges for span lengths and concrete compressive strengths, for each type of bridge surveyed.

Shorter Spans

Slab, voided slab and double T beams are more prevalent for shorter span lengths. Table 10 provides the ranges for span length and f'_c for these structural types, as reported by the DOTs. In addition the reported prevalence of each type for HSC prestressed bridge members is provided (as % HSC), although different interpretations of this information appear to have been made. The typical range for shorter spans is from approximately 30 to 60 ft. and the typical range for f'_c varies from approximately 3500 to 6000 psi. An f'_c of 8000 psi was also reported and the New York DOT reported the use of voided slabs for beams spanning up to 100 ft. with f'_c up to 10000 psi.

Longer Spans

Closed box cast-in-place (CIP) beams, AASHTO beams, bulb beams, and box beams are more prevalent for longer span lengths. Tables 11 through 14 show the ranges for span length and f'_c for these structural types. In addition, the reported prevalence of each type for HSC prestressed bridge members is provided, although this parameter seems to have different interpretations among the respondents. The typical range for longer span lengths is from approximately 60 to 150 ft. and the typical range for specified concrete strengths at service (f'_c) varies from approximately 6000 to 10000 psi. An f'_c of 13000 psi was also reported.

Table 11 shows that the CIP closed box beams can be used for spans from 50 to 150 ft. with f'_c of 6000 psi, but they are rarely used. Table 12 indicates that the AASHTO beams are used for a variety of span lengths, with the typical span lengths ranging from approximately 75 to 130 ft. and the typical f'_c value ranging from approximately 6000 to 8000 psi. In particular, the prevalent range for span length is 100 to 120 ft. It was also reported by TxDOT that span lengths up to 155 ft. and f'_c of 14000 psi can be used.

Table 13 shows that the bulb beams are also used for a wide range of span lengths. However, the most typical range for span lengths is approximately 95 to 135 ft., and the typical range for f'_c is about 6000 to 8000 psi. In particular the most typical span length is 115 ft. followed by the span of 135 ft.

Table 14 shows that box girders are also used for a large range of span lengths, although they are not widely used. The most typical range for span lengths is approximately 55 to 115 ft., and the typical range for f'_c is approximately 6000 to 8000 psi. TxDOT's Austin and Houston offices collectively use the box girder section for span lengths ranging from 55 to 115 ft. with f'_c values from 6000 to 8000 psi.

Table 15 shows other beam types that are used for a variety of span lengths and concrete strengths. These beams are specific for one or more states and are not widely used. Among these beam types are the tri-deck, the inverted T, the side-by-side box beams, the Missouri beams, the Minnesota beams, and the Texas U beams. In particular, the Texas U is being used not only in the state of Texas, but also in other states such as Colorado and New Mexico. In this case, the typical range for the span length is approximately 75 to 140 ft. The typical f'_c ranges from approximately 6000 to 10000 psi, although New Mexico uses an f'_c up to 12000 psi.

CONCLUSIONS

A survey was conducted to determine the current state of practice for the design of high strength concrete (HSC) prestressed bridge girders among Departments of Transportation (DOTs) in the United States. Out of the 52 state DOTs in the United States, 41 provided a response. Responses were received during a six-month period spanning from June through November of 2002. The major findings are summarized below.

The adoption of the *AASHTO LRFD Bridge Design Specifications* by state DOTs is gradual. The *AASHTO Standard Specifications for Highway Bridges*, 16th Edition, is the most popular code for bridge design in current practice. In most cases where the LRFD Specifications are used, their implementation is partial, and most states plan complete implementation in the period of 2003 to 2007.

The responding state DOTs have a large variation in the number of new bridges constructed, with a range of 4 to 400 bridges per year. Of these numbers, the percentages of bridges constructed with HSC prestressed girders range from 0 to 100 percent among the DOTs. Nevertheless, the total number of bridges constructed per year using HSC prestressed girders is significant. HSC prestressed girders are widely used in current practice, with 85 percent of the responding DOTs indicating that they use f'_c values at service in the range of 6000 to 8000 psi. It was found that in some cases (in general when $f'_{ci} > 6000$ psi) mixture designs are governed by the specified concrete compressive strength at release. Thus, the specified release strength tends to be critical for HSC prestressed girder production.

The responses indicate that almost half of the DOTs have some concerns related to the use of HSC, including the following.

- Maximum span lengths are limited by transportation of the girders.
- Design parameters in the AASHTO Specifications do not specifically address HSC. As such, several DOTs are reluctant to specify concrete compressive strengths at service higher than 8500 psi.
- Initial cracking of girders may occur during casting and before the release stage.
- There are difficulties in providing 0.6 in. diameter strands at the proper spacing for some standard girder configurations.
- In some areas, suitable aggregates are not available; and in some cases, there are no qualified precasters to produce HSC prestressed girders.
- Research is needed to address critical issues, such as over-estimation of losses and determination of creep, shrinkage and camber for HSC.

The survey indicates that most of the DOTs have not made adjustments to the design specifications for HSC prestressed bridge girders. Seven DOTs have made in-house adjustments that include modifications to the allowable stresses and equations for modulus of elasticity, losses, creep and camber.

It was found that the HSC prestressed girder types that are most popular among the DOTs that responded include the AASHTO beam, followed by the bulb beam, and the box girder. Voided slabs, slabs, double T beams and closed box cast-in-place (CIP) beams are the structural types with less use, although the closed box CIP girder is used for long spans (typically up to 150 ft.). Texas U beams are used not only in Texas, but also in Colorado and New Mexico. Closed box CIP beams, AASHTO beams, bulb beams, and box beams are more prevalent for longer span lengths. For longer span girders, typical spans range from approximately 60 to 150 ft. and the specified concrete strengths at service generally varies between 6000 to 10000 psi.

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REFERENCES

1. Hueste, M., Trejo, D., Cline, D. and Keating, P. (2003). “Investigation of Flexural Design Parameters for High Strength Concrete Prestressed Bridge Girders – Project Overview,” *Research Report 2101-1*, Texas Transportation Institute and Texas Department of Transportation, in preparation.
2. Hueste, M. and Cuadros, G. (2003), “Flexural Design of High Strength Concrete Prestressed Bridge Girders – Review of Current Practice and Parametric Study,” *Research Report 2101-3*, Texas Transportation Institute and Texas Department of Transportation, in review.
3. AASHTO (1996). *Standard Specifications for Highway Bridges*, 16th Ed. American Association of State and Highway Transportation Officials (AASHTO), Washington, D.C.
4. AASHTO (2002). *Standard Specifications for Highway Bridges*, 16th Ed., 2002 Interim Revisions. American Association of State and Highway Transportation Officials (AASHTO), Washington, D.C.
5. AASHTO (2002). *AASHTO LRFD Bridge Design Specifications*, 2nd Ed., 2002 Interim Revisions. American Association of State and Highway Transportation Officials (AASHTO), Washington, D.C.
6. PCI (1997). *Bridge Design Manual*, 4th Ed., Precast Concrete Institute (PCI), Chicago, Illinois.
7. ACI Committee 363 (1997). “State of the Art Report on High Strength Concrete,” *ACI 363R-92 (reapproved 1997)*, American Concrete Institute (ACI), Farmington Hills, Michigan.
8. TxDOT (2001). *Bridge Design Manual*, Texas Department of Transportation (TxDOT), Bridge Division.
9. Hueste, M., Chomprea, P., Trejo, D., Cline, D., and Keating, P. (2003). “Mechanical Properties of High Strength Concrete for Prestressed Concrete Bridge Girders,” *Research Report 2101-2*, Texas Transportation Institute and Texas Department of Transportation, in review.

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FIGURE 1	Prevalence of bridge types with HSC prestressed girders.
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TABLE 1 Current Specifications and Implementation Plans

Department of Transportation	Q 1		Q 2	Q 3
	Current Specification		LRFD is Used	LRFD is Not Used
	LRFD (5)	Standard (3,4)	Date of Implementation	Date of Expected Implementation
Alabama		x (2000)		2007
Alaska	x (-)		1997 (partial)	2007
Arkansas		x (1996)		2007
California		x (2000)		2004
Colorado	x (current)		2000	
Connecticut	x (-)	x (-)	2000 (partial)	2004
Florida	x (1998)	x (1996)	1998	
Georgia		x (-)		2005
Hawaii	x (1998)		1996	
Idaho	x (2001)		2000	
Illinois		x (1996)		2007
Iowa	x (1998)	x (1996)	2000 (partial)	2003
Kansas	x (1998)		1999	
Kentucky		x (current)		2007
Louisiana	x (current)	x (1996)	2001(partial)	2005
Massachusetts	x (-)	x (1996)	1998 (partial)	2007
Michigan		x (1996)		2007
Minnesota	x (1998)	x (1996)	1998 (partial)	2002
Mississippi		x (1996)		2005
Missouri		x (1996)		2005
Montana	x (1998)	x (1996)	1994	
Nevada		x (1996)		2003
New Hampshire		x (1996)		2003
New Jersey	x (1996)		2000	
New Mexico		x (1996)		2007
New York		x (1996)		2005
North Carolina		x (1996)		2007
North Dakota		x (1996)		
Ohio		x (1996)		
Oklahoma	x (-)			
Pennsylvania	x (1998)		1997	
Rhode Island		x (1996)		2007
South Carolina	x (-)	x (-)	2000	
South Dakota		x (1996)		2007
Tennessee		x (1996)		2007
Texas – Austin	x (-)	x (-)	2002 (partial)	2007
Texas – Houston		x (1996)		2005
Vermont		x (2001)		2003 – 2004
Virginia		x (1996)		2007
Washington	x (1998)		1995,1998	
Wisconsin		x (2000)		2005
Undisclosed DOT		x (2002)		

TABLE 2 Additional Documents and References

Department of Transportation	Q 4	Q 5
	References for Prestressed Girder Design	References for HSC Member Design
Alabama	PCI Manual	Texts
Alaska	Internal Procedures	
Arkansas	PCI / PCA	
California	CA-BD-Manual	PCI Manual
Colorado	CO-BD-Manual	
Illinois	PCI Manual	
Iowa	IA-BD-Manual	PCI Manual
Louisiana		Internal Research
Massachusetts	PCI Manual/Leap Software	
Michigan	PCI Manual	
Minnesota	PCI Manual	
Montana	PCI Manual	
New Hampshire	PCI Manual	
New Jersey	NJ-BD-Manual	
New York	NY-BD-Manual	PCI Manual
Ohio	PCA Publication	Texts
Pennsylvania	PA-BD-Manual	
Rhode Island		PCI Manual/ACI Code
South Carolina	PCI Manual	Leap Software
South Dakota	PCI Manual	Journals
Texas - Austin	PCI / PRSTRS14 Manuals	
Vermont	PCI Manual	
Virginia	ACI Code	
Washington	WS-BD-Manual	PCI-BD Manual

BD Manual = Bridge Design Manual

PCA = Portland Cement Association

PCI = Precast/Prestressed Concrete Institute

TABLE 3 Number of HSC Prestressed Bridges Constructed (Q 7)

Department of Transportation	Total No. of Bridges Constructed per Year	% HSC ($f'_c > 6$ ksi)
Alabama	50	50%
Alaska	20	100%
Arkansas	70	0%
California	200	10%
Colorado	48	40%
Connecticut	22	0%
Florida	60	90%
Georgia	100	90%
Hawaii	5	80%
Idaho	10	85%
Illinois	400	0%
Iowa	30	90%
Kansas	149	15%
Kentucky	80	15%
Louisiana	15	2%
Massachusetts	20	0%
Michigan	70	85%
Minnesota	45	75%
Mississippi	100	0%
Missouri	250	1%
Montana	18	60%
Nevada	12	0%
New Hampshire	30	10%
New Jersey	31	1%
New Mexico	10	25%
New York	236	30%
North Carolina	150	30%
North Dakota	8	25%
Ohio	150	30%
Oklahoma	160	67%
Pennsylvania	250	50%
Rhode Island	4	100%
South Carolina	50	5%
South Dakota	12	10%
Tennessee	80	60%
Texas - Austin	360	18%
Texas – Houston	50	75%
Vermont	40	15%
Virginia	125	30%
Washington	30	80%
Wisconsin	200	10%
Undisclosed DOT	40	0%

TABLE 4 Typical Range for Specified Concrete Strength for Prestressed Girders (Q 8)

Department of Transportation	Range of Specified Concrete Strength																
	f'_{ci} at Transfer (ksi)							f'_c at Service (ksi)									
	3	4	5	6	7	8	9	4	5	6	7	8	9	10	11	12	
Alabama			x	x	x				x	x	x	x					
Alaska		x	x	x	x						x						
Arkansas		x							x								
California		x	x	x				x	x	x	x	x					
Colorado			x	x	x				x	x	x	x					
Connecticut		x							x	x							
Florida		x	x	x	x				x	x	x	x					
Georgia		x	x	x	x					x	x	x	x	x			
Hawaii		x	x	x						x	x						
Idaho		x	x						x	x							
Illinois			x							x							
Iowa		x	x	x	x				x	x	x	x	x				
Kansas		x	x						x	x							
Kentucky		x	x	x					x	x	x						
Louisiana		x	x						x	x							
Massachusetts		x	x	x						x	x	x					
Michigan	x	x	x	x					x	x	x						
Minnesota		x	x	x	x				x	x	x	x					
Mississippi		x	x						x	x							
Missouri				x	x						x	x	x	x			
Montana		x	x	x					x	x	x						
Nevada	x	x						x	x								
New Hampshire		x	x						x	x	x	x					
New Jersey		x							x	x							
New Mexico		x	x	x	x	x	x			x	x	x	x	x	x	x	
New York			x	x	x						x	x	x	x			
North Carolina		x	x						x	x	x	x					
North Dakota		x	x	x					x	x	x						
Ohio			x								x						
Oklahoma																	
Pennsylvania			x	x	x					x	x	x					
Rhode Island		x	x							x	x	x	x				
South Carolina	x	x	x						x	x	x	x					
South Dakota			x	x	x					x	x	x					
Tennessee		x	x	x	x	x			x	x	x	x	x	x			
Texas - Austin		x	x	x					x	x	x	x					
Texas - Houston		x	x	x					x	x	x	x					
Vermont	x	x	x					x	x	x							
Virginia										x	x	x					
Washington					x	x							x				
Wisconsin			x							x	x	x					
Undisclosed DOT		x							x	x							

TABLE 5 Specific Information for Required Transfer Strength (Q 9)

Department of Transportation	Yes	No	Specific Information
Alabama	x		Some use of high earlier strength additives are used if release is more than 6500 psi. Long term strength gain is less when high early strength is attained
Alaska	x		Recent job with $f'_{ci}=7250$ psi had 16 hr. break of 10000 psi. Same mix design later provided 6800 psi break.
Arkansas	x		This is being done but we do not observe lab tests for 28-day compressive strength.
California	x		Normally f'_c provided by precasters exceeds f'_c specified significantly.
Colorado	x		No. Varies widely
Connecticut		x	
Florida	x		For large beams, cycle times of three days or less are recommended to eliminate shrinkage cracking. Therefore, FDOT limits release strengths to 80 percent of f'_c based on typical strength gain curves. Many prestressers still utilize different preapproved mixes and depending on time of year, project release requirements etc. may use the mix that produces the optimum turn-around time. It is not uncommon for a 5500 psi mix to break in the 7500 psi range.
Georgia	x		Probably so for 6000 psi concrete. For $f'_c=6000$ psi concrete (design), actual strengths usually range from 7000 to 8000 psi
Illinois		x	
Iowa	x		Need to meet release strengths in 18 hours. Need to meet 28 day strength quickly so beams can be shipped early.
Kansas		x	Not done in Kansas due to the fact that Kansas has relatively poor aggregates, therefore higher strengths are not easily achieved without a significant increase in cost.
Kentucky		x	
Louisiana		x	
Massachusetts		x	
Michigan		x	This is rarely a problem for HSC.
Minnesota	x		We have two methods being in use. First is to use high-early cement to obtain a high initial concrete strength, but final strengths then take much longer to achieve. The other method, as you described, does provide final strengths in excess of 10 ksi. No information on comparison of f'_{ci} and f'_c required.
Missouri	x		Of two bridges constructed, two set of values for concrete strengths at transfer and at service are as follows. Case 1: Specified $f'_{ci}=5500$ psi, Specified $f'_c=10000$ psi, Actual $f'_c=12300$ psi. Case 2: Specified $f'_{ci}=7500$ psi, Specified $f'_c=10000$ psi, Actual $f'_c=11400$ psi. In contrast, projects currently in design or construction phase have specified f'_c of 500 to 1500 psi above f'_{ci} . Based on this we would not be surprise if we start seeing significantly higher f'_c than specified.
Montana	x		From approximately 300 tests for 28-day cylinder breaks from recent prestressed beams, the average strength was 9200 psi, median was 9300 psi, and the standard deviation was 1600 psi. It appears that the higher the transfer strength in a given amount of time, the lower percentage gain in final strength.
New Hampshire		x	We have not observed precasters designing mixes specifically to achieve a one day turnaround.
New Jersey	x		To assure that desired strengths are achieved NJDOT specifies mix designs that ultimately produced higher strengths in service. Fabricators are awarded bonuses for good production and penalized for bad production. Mix proportion concrete strength approximately 10 percent higher than specified compressive strength.
New Mexico		x	No issues brought to us by prestress plant.
New York	x		Precasters generally use mix designs with expected 28 days strength 10 to 15 percent above what is required by the designs. Benefits: 1- Relatively early release of beds. 2- Allow shipping earlier than 28 days since girders could be shipped once compressive strengths are above the required minimum.

Department of Transportation	Yes	No	Specific Information
North Carolina	x		Precasters typically focus on achieving initial strengths (f'_{ci}) and acceptance strength (f'_c) by using high early cement and heat curing methods. Typically f'_{ci} is achieved within 1 to 2 days and f'_c is achieved within 14 to 18 days. At acceptance strength, f'_c is usually 200 to 500 psi greater than the f'_c specified for designs. Unfortunately no testing is done after acceptance. Therefore, 28 days strength is not known to compare to actual design strength.
North Dakota		x	The beams do not gain much strength after f'_{ci} has been reached.
Oklahoma	x		For f'_c less than and equal to 8000 psi (+/- 75 percent). For f'_c more than 8000 psi (+/- 70 percent).
Pennsylvania	x		We see that the transfer strength controls the design, so we use higher transfer and then higher 28 day.
Rhode Island	x		Typically higher transfer strengths are attained with accelerated curing systems heat/steam. High early strength mixes are known to attain lower strengths at 28 days than if cured under ambient conditions- the strength tends to flatten out at 7 days. It is difficult to list a correlation between the strength at release and the strength at service conditions.
South Carolina	x		Precasters overdesign their mix for faster production.
South Dakota	x		This occurs quite often. Fabricators who rely on radiant heat curing use mix designs with higher f'_c than fabricators who use steam curing. Unable to give more specific information.
Tennessee		x	We do not see this occurring too much on high strength girders, but it does tend to occur on normal strength girders.
Texas – Austin	x		Generally, 30 to 50 percent higher.
Texas - Houston	x		Information not available.
Vermont	x		Most of our prestressed structures are constructed with beams precast under this scenario, especially with high strength transfer in short time frames. We have not made any analysis of what effect this has. The bridges seem to perform well.
Washington	x		Designs are controlled by f'_{ci} but high strength at release does not result in a significantly larger f'_c . Observation: $f'_{ci} = 7500$ psi, then reduces slightly up to 7 days, then increases to about $f'_c = 10000$ psi at 28 days.
Wisconsin		x	

TABLE 6 Concerns Related to the use of HSC (Q 10)

DOT	Yes	No	Specific Information
Alabama		x	Have used HSC for several years without problems.
Alaska	x		All parameters in the design of HSC/HPC must be optimal to consistently provide satisfactory concrete strengths.
Arkansas		x	Prestressed bridge girders are not a predominant structure type in Arkansas.
California		x	
Colorado	x		With current technology it is difficult to take advantage of concrete strengths more than 9000 psi.
Connecticut		x	
Florida	x		FDOT typically utilizes HSC with 0.6 in. low lax diameter strands on a 2" grid which slightly violate the AASHTO minimum spacing between strands, but makes the best use of materials. In a few cases stress risers have occurred at the ends of long girders at release due to the large cambers. Various cushioning mechanism have been utilized to solve this problem. In a few cases large camber growth has been a concern requiring the beam to penetrate the deck slab at midspan.
Georgia	x		Still concerned about final camber.
Hawaii		x	
Illinois		x	The use of long spans is limited by transportation of girders. HSC may help to increase girder spacing and lowering the number of girders.
Iowa	x		Predicting camber in HSC. Predicting losses. Transportation of long beams. Anchorage of reinforcement.
Kansas	x		None, other than the producer's ability to get the HSC.
Kentucky		x	
Louisiana	x		Initial cracking of girders during pouring and before release stage. We limited temperature to 160° F max. During cold weather, steam is added which tends to increase initial.
Massachusetts	x		Shrinkage and cracking, magnitude and size.
Michigan		x	No concerns with HSC in ranges less than 7000 psi.
Minnesota		x	
Mississippi		x	
Missouri	x		We are concerned in focusing on what is economically feasible and beneficial in Missouri. Striving for cost-saving designs and improved performance via HSC according to locally available materials.
Montana		x	
Nevada	x		Non-availability of suitable aggregates in the Northern part of the state. There are not qualified precasters within the state.
New Hampshire	x		Specifications need to be upgraded for HSC.
New Jersey	x		Long term QC testing such as creep testing becomes a concern. We encourage fabricators to have mix designs pre-approved.
New Mexico		x	
New York	x		Since HSC has no criteria to control the penetration of chlorides when exposed to them, corrosion of steel is a problem. NYSDOT is moving to HPC with lower permeability. We are also using curing corrosion inhibitors and sealers.
North Dakota		x	
Ohio	x		Damage due to collision. Damage in grade separations.
Oklahoma		x	
Pennsylvania	x		For very high strengths, over 9000 psi, we are concerned about the applicability of the Specifications.
Rhode Island	x		Early tensile cracks at the transfer stress.
South Carolina	x		
South Dakota	x		Deflections, camber, and losses.
Texas – Austin		x	
Vermont	x		Brittle failure. Need for more prestress strands to take advantage of HSC. This then requires more steel to be added to already congested end beam detail.
Virginia		x	
Washington	x		Curing, over estimating losses, over-estimating creep and camber.
Wisconsin		x	
Undisclosed DOT	x		

TABLE 7 Adjustments to Design Specifications for HSC Prestressed Bridge Girders (Q 11)

DOT	Yes	No	Specific Information
Alabama		X	Developed some HPC mix designs for a HPC showcase project.
Alaska		X	
Arkansas		X	
California		X	
Colorado		X	
Connecticut		X	
Florida		X	
Georgia		X	
Hawaii		X	
Idaho		X	
Illinois		X	
Iowa		X	
Kansas	X		Reduced the allowable tension in the precompressed tensile zone caused by the prestressing force, service loads and prestressed losses to $0.125 \sqrt{f'_c}$ ($3.95 \sqrt{f'_c}$ in psi units). This KsDOT policy is for fatigue considerations should cracking of the beam occur.
Kentucky		X	
Louisiana	X		We have developed special provisions for our HPC projects based on our sponsored research. Our current research will be completed in 2003. We hope to change allowable stresses based on the 2003 research.
Massachusetts		X	
Michigan		X	
Minnesota	X		The only modification in design is the method to calculate the modulus of elasticity "E _c ". We use the equation developed by U of M for our high strength mixes.
Mississippi		X	
Missouri		X	No, but a research study currently underway with the University of Missouri-Rolla, R100-002, is intended to provide results which will validate or recommend design assumptions for HPC.
Montana		X	
Nevada		X	
New Hampshire		X	
New Jersey		X	
New Mexico		X	New Mexico State University did some prestress loss measurements using fiber optics. Losses were within design assumptions.
New York		X	
North Carolina		X	
North Dakota		X	
Ohio		X	
Oklahoma		X	
Pennsylvania		X	
Rhode Island		X	
South Carolina		X	
South Dakota	X		Modification of the method to compute the modulus of elasticity.
Tennessee		X	
Texas – Austin		X	
Texas – Houston		X	
Vermont	X		Our specifications were developed regionally with neighboring states. Contact the new England region of PCI for more info.
Virginia	X		Not using LRFD
Washington	X		Not based on research findings but based on in-house practice. Modification of creep equation, modification of methods to compute losses, camber, and modification of the allowable stresses. Design memorandums (concrete density, shear, bursting, etc.)
Wisconsin		X	

TABLE 8 Typical Bridges with HSC Prestressed Bridge Members¹

Span Type	Structural Type	Span (range in ft.)	f'_c (range in psi)	Percentage
Simple Span	Slab			
	Voided Slab			
	Double T			
	Closed Box CIP			
	AASHTO Beam			
	Bulb			
	Box Girder			
	Other (describe)			
Continuous Span ²	Slab			
	Voided Slab			
	AASHTO Beam			
	Post-tensioned AASHTO			
	Beam			
	Bulb			
	Box			
	Other (describe)			

1. This table is blank copy of the form used in the survey.
2. For this study, the term “continuous span” refers to the case where the girders are continuous over a support. When continuity is provided within the cast-in-place slab only, this is considered a “simple span.”

TABLE 9 Typical Ranges for Span Length and Concrete Compressive Strength

Structural Type	Span Length (ft.)				Concrete Compressive Strength, f'_c (ksi)				
	30-60	60-90	90-120	120-150	3.5-6	6-8	8-10	10-12	14
Slab	X				X	*	*		
Voided Slab	X				X	*	*		
Double T	X				X	*			
Closed Box CIP*	X	X	X	X	X				
AASHTO	*	X	X	X	*	X	X	*	**
Bulb	*	X	X	X	*	X	X		
Box Girder	*	X	X	*	*	X			
Other (U beam)	*	X	X	X		X	X	*	

* Rarely used

** One case

TABLE 10 Typical Bridges with HSC Prestressed Members – Shorter Spans

Structural Type	DOT	Span (ft.)							f'_{c} (ksi)										% HSC
		20-30	30-40	40-50	50-60	60-70	70-80	80-110	3	4	5	6	7	8	9	10			
Slab	California	x	x						x	x	x						5%		
	Colorado	x	x							x							0%		
	Florida	x	x								x	x					5%		
	Hawaii	x	x									x	x				20%		
	Illinois		x							x	x						100%		
	Montana	x								x	x						0%		
	New York	x											x	x	x	x	1.5%		
	Texas – Austin		x									x	x				0.4%		
	Vermont	x							x	x							5%		
	Virginia	x	x	x						x							-		
	Washington	x	x	x	x					x	x						0%		
	Total	9	8	2	1				2	7	5	3	3	1	1	1			
Voided Slab	Alaska		x										x				10%		
	California	x	x	x					x	x	x	x					5%		
	Idaho	x	x	x							x	x					90%		
	Illinois			x	x	x	x			x	x						100%		
	New York		x	x	x	x	x	x					x	x	x	x	20%		
	North Carolina		x	x							x	x	x	x			20%		
	Vermont		x	x	x				x	x							62%		
	Virginia	x	x	x						x							-		
	Washington	x	x	x	x	x				x	x	x					60%		
	Total	4	8	8	4	3	2	1	2	5	5	4	3	2	1	1			
Double T	California		x	x	x				x	x	x	x					5%		
	Minnesota	x	x	x	x							x	x				-		
	Oklahoma		x	x	x									x			5%		
	Texas – Austin		x	x	x							x	x				0.5%		
	Vermont		x	x					x	x							12%		
	Total	1	5	5	4				2	2	1	3	2	1					

TABLE 11 Typical Bridges with HSC Prestressed Members – Structural Type: CIP Closed Box Beam

DOT	Span (ft.)						f'_c (ksi)			% HSC
	50-60	60-80	80-100	100-120	120-130	130-140	4	5	6	
California ¹			x	x	x	x	x	x		70%
Colorado ²	x	x	x	x	x	x	x	x	x	0%
Washington	x	x	x	x	x	x	x	x		0%
Total	2	2	3	3	3	3	3	3	1	

¹ CA DOT reported span lengths up to 600 ft.

² CO DOT reported span lengths up to 200 ft.

TABLE 12 Typical Bridges with HSC Prestressed Members - Structural Type: AASHTO Beam

DOT	Span (ft.)							f'_c (ksi)							% HSC
	40-60	60-80	80-100	100-120	120-140	140-150	150-160	5	6	7	8	9	10	11-14	
Alabama			X	X					X	X	X				40%
California ¹	X	X	X	X				X	X	X					10%
Florida			X	X				X	X	X	X				35%
Georgia		X	X	X					X	X	X	X	X		30%
Hawaii	X	X	X	X	X				X	X					80%
Idaho	X	X	X	X				X	X						90%
Illinois ²	X	X	X					X	X						small
Kansas				X					X						30%
Kentucky					X			X	X	X					5%
Louisiana		X	X	X	X								X		2%
Michigan				X					X	X					50%
Minnesota	X	X	X	X	X	X	X		X	X	X				95%
Mississippi		X	X	X					X						50%
Montana	X	X	X	X	X	X		X	X	X					70%
New Hampshire		X	X					X	X	X	X				10%
New Jersey ³			X	X	X	X	X		X	X	X				
New Mexico			X	X					X	X	X	X	X		30%
New York		X	X	X	X					X	X	X	X		1%
North Carolina	X	X	X	X	X			X	X	X	X				70%
North Dakota				X	X	X			X	X					10%
Ohio		X	X	X	X	X	X			X					45%
Oklahoma	X	X	X	X							X	X	X		85%
Pennsylvania		X	X	X	X	X			X	X	X				50%
South Dakota	X	X	X						X	X	X				50%
Texas - Austin			X	X	X	X			X	X	X	X	X	X	76.7%
TX - Houston		X	X	X				X	X	X	X				50%
Vermont ⁴	X	X	X					X							5%
Virginia	X	X	X						X	X	X				-
Wisconsin	X	X	X	X				X							30%
Total	12	19	24	22	12	7	3	10	22	20	14	5	6	1	

¹ CA DOT reported $f'_c = 4$ ksi² IL Beam³ WA DOT reported span lengths up to 222 ft.⁴ VT DOT reported $f'_c = 4$ ksi

TABLE 13 Typical Bridges with HSC Prestressed Members - Structural Type: Bulb Beam

DOT	Span (ft.)							f'_c (ksi)								% HSC
	40-60	60-80	80-100	100-120	120-140	140-150	150-160	4	5	6	7	8	9	10		
Alabama				x	x					x	x	x				60%
Alaska		x	x	x	x					x	x					90%
California			x	x	x	x		x	x	x	x					10%
Colorado	x	x	x	x	x	x	x			x	x	x	x			34%
Florida				x	x	x				x	x	x				10%
Georgia			x	x	x					x	x	x				70%
Idaho	x	x	x	x	x					x	x					90%
Illinois			x	x	x	x			x	x						small
Iowa	x	x	x	x	x				x	x	x	x	x			15%
Kansas				x	x	x				x	x	x				100%
Massachusetts			x	x									x			50%
Michigan					x	x				x	x					20%
Mississippi						x				x						100%
Missouri				x							x					2 bridges
Montana	x	x	x	x	x				x	x	x					70%
New Hampshire		x	x	x					x	x	x	x				88%
New Mexico			x	x	x					x	x	x	x	x		30%
New York		x	x	x	x						x	x	x	x		1%
North Carolina			x	x	x				x	x	x	x				80%
Ohio					x	x	x				x					5%
Oklahoma				x	x								x	x	x	10%
Virginia	x	x	x							x	x	x				
Washington	x	x	x	x	x	x	x						x	x	x	100%
Wisconsin				x	x	x			x							70%
Total	6	9	15	20	19	10	3	1	7	17	18	13	6	4		

TABLE 14 Typical Bridges with HSC Prestressed Members - Structural Type: Box Girder

DOT	Span (ft.)							f'_c (ksi)					% HSC
	40-60	60-80	80-100	100-120	120-140	140-150	150-160	4	5	6	7	8	
California				x	x	x		x	x	x	x		5%
Colorado	x	x	x	x	x				x	x	x	x	10%
Florida					x	x						x	5%
Idaho		x							x	x			90%
Kentucky			x						x	x	x		10%
Massachusetts			x	x								x	50%
Ohio	x	x							x	x	x		50%
Pennsylvania				x							x	x	50%
Rhode Island	x	x	x								x	x	85%
Texas - Austin			x	x							x	x	5.7%
Texas - Houston	x	x	x	x					x	x	x	x	5%
Vermont	x	x						x	x	x			16%
Washington						x	x	x	x				0%
Total	4	5	5	5	3	3	1	3	7	9	7	5	

TABLE 15 Typical Bridges with HSC Prestressed Members - Structural Type: Other

Structural Type	DOT	Span Length (ft.)								f'_c (ksi)							% HSC
		40-60	60-80	80-100	100-110	110-120	120-130	130-150	150-200	5	6	7	8	9	10	11-12	
Inverted T	Kansas	x	x	x								x	x				100%
Side by Side Box Beams	Michigan				x	x	x	x		x	x	x					30%
PS Rect. Beam	Minnesota	x									x	x	x				5%
MO Beam	Missouri	x	x									x	x	x	x		3 bridges
Tri-Deck	Idaho	x								x	x						90%
	Montana	x								x	x	x					70%
Channel Bridge	New York *					x	x	x	x			x	x	x	x		0.50%
MN Beam	South Dakota			x	x	x	x				x	x	x				50%
Deck Bulb T	Washington	x	x	x	x	x	x	x	x	x	x	x	x				16.7%
U Beam	Colorado*	x	x	x	x	x	x	x	x	x	x	x	x	x			2%
	New Mexico			x	x	x	x						x	x	x	x	40%
	TX – Austin				x	x	x				x	x	x				
	TX - Houston			x	x	x	x			x	x	x	x				75%
Total		7	4	5	6	7	7	4	3	5	8	10	9	4	3	1	

*Colorado, New York and Washington reported span lengths up to 200 ft., 165 ft., and 160 ft. respectively.

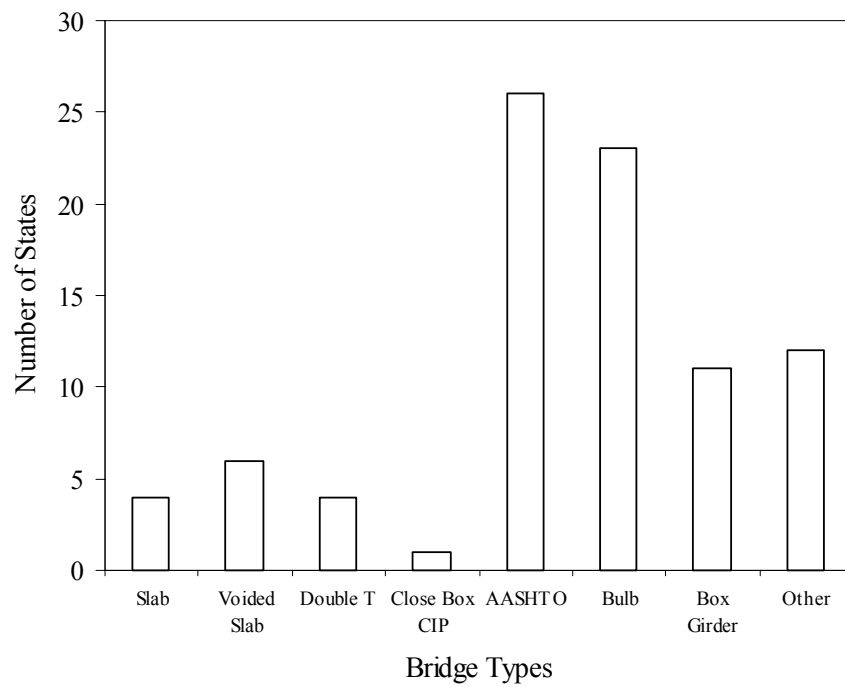


FIGURE 1 Prevalence of bridge types with HSC prestressed girders.